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FINAL TECHNICAL REPORT FOR 18,000 BTUH COMPACT VERTICAL AND HORIZONTAL TOTAL ENVIRONMENTAL CONTROL SYSTEM (TECS), 0500.0136

VSE Corporation
2550 Huntington Avenue
Alexandria, VA 22303-1499

31 January 1989

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Approved for public release; distribution is unlimited.

Prepared for:

US Army Belvoir Research, Development and Engineering Center
Environmental Control and Systems Support Division (STRBE-FED)
Fort Belvoir, VA 22060-5606

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VSE PROVIDED PROTOTYPE MANUFACTURING, ENGINEERING EVALUATION AND TESTING SERVICES TO SUPPORT DEVELOPMENT OF TWO 18,000 BTUH HORIZONTAL AND TWO 18,000 BTUH VERTICAL TECS AIR CONDITIONERS. THESE FOUR AIR CONDITIONERS WERE FABRICATED FOR GOVERNMENT TESTING SUCH THAT COMPARATIVE DATA COULD BE GENERATED AND EVALUATED. CONTROLS TESTING AND RUN-IN TESTING WERE PERFORMED ON THREE OF THE FOUR FABRICATED UNITS. ONE UNIT WAS DELIVERED WITHOUT A MOTOR CONTROLLER AND THEREFORE NOT FORMALLY TESTED. THESE AIR CONDITIONERS WERE ALSO USED TO EVALUATE USE OF COMMERCIAL COMPRESSORS.

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SUMMARY

Task Order 0136 required that VSE provide general technical services to the Environmental Control and Systems Support Division of the Belvoir Research, Development and Engineering Center, Fort Belvoir, Virginia in support of the Government's 18,000 (18K) BTUH Total Environmental Control System (TECS) development effort. A total of four (4) 18K BTUH TECS air conditioners were modified and reconfigured by incorporating motor controllers into two (2) 18K BTUH standard vertical air conditioners and two (2) standard horizontal air conditioners. The four units are referred to as "baseline" units and were used to acquire comparative test data. These baseline units were first tested by the Government in their standard configuration. The units were then provided as Government Furnished Equipment (GFE) to VSE for incorporation of motor controllers and associated components to convert them into TECS units. The Government is currently testing the baseline units in order to compare test data with previous test data resulting from the unmodified baseline tests.

The baseline units were also used to evaluate the suitability of commercial compressors for a possible replacement of the military compressor in the 18K BTUH TECS air conditioners. Commercial compressors were not included in the final TECS unit design due to unfavorable test results.

PREFACE

This Final Technical Report was prepared under Contract No. DAAK70-86-D-0023, Task Order 0136, for the Belvoir Research, Development and Engineering Center (Belvoir), Fort Belvoir, Virginia. Mr. Thomas Sgroi served as the Belvoir Contracting Officer's Representative, telephone no. (703) 664-6031.

This report represents the final effort for support of the 18K BTUH TECS baseline air conditioners to be provided under Task Order 0136. The required effort in the Task Order statement of work is quoted below:

> "The purpose of this Task Order is to provide engineering evaluation, prototype manufacturing, documentation and testing services in support of incorporating motor controllers into two (2) 18,000 BTUH compact Vertical and two (2) Horizontal Military Standard Air Conditioners which are being tested by the Government to establish baseline data for comparative purposes. This modification will result in air conditioners with "soft start" electronics installed internally. "Soft-start" is defined as operating the air conditioner such that start-up current does not exceed full load steady-state current required for the air-conditioner (with controls). These modified air conditioners shall be referred to as Total Environmental Control Systems (TECS). The contractor shall utilize knowledge gained during the performance of Contract No. DAAK70-86-D-0023, Task Order No. 0074 to accomplish this task."

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1.0 INTRODUCTION

Task Order 0136 required VSE Corporation to provide technical support for the Government's 18,000 (18K) BTUH Total Environmental Control System (TECS) Program. The primary purpose of this task was to provide shop fabrication services to modify and reconfigure four (4) 18K BTUH TECS air conditioners by incorporating motor controllers into two (2) 18K BTUH standard vertical air conditioners and two (2) standard horizontal air conditioners. TECS unit fabrication was performed in accordance with the Government Furnished Data (GFD) Level 1 vertical and horizontal TECS drawing packages prepared under Task Order 0074, Contract No. DAAK70-86-D-0023. The four TECS units which were modified and reconfigured were designated as "baseline" units. These four prototype units were to be used to acquire comparative data between the new TECS design and the standard 18K BTUH Army air conditioner. The four baseline units augmented the eight (8) "reliability" units fabricated under Task 0074. Basically the reliability units are intended for long duration reliability testing while all other short term testing such as capacity, EMI, vibration, rain, high/low temperature operation, coil frost, noise, etc. will be performed on the baseline units. The baseline units were also used to evaluate use of commercial compressors in the TECS unit.

2.0 DISCUSSION

2.1 General. VSE provided prototype manufacturing, testing, documentation and engineering evaluation (as required) services in support of motor controller incorporation into four 18K BTUH air conditioners.

Four (4) 18K BTUH TECS air conditioners were fabricated and delivered to Belvoir. Controls and run-in testing were performed on three of the air conditioners. Testing was not performed on the fourth unit due to nonavailability of a motor controller.

No design modifications were incorporated into the GFD Level 1 drawing package as a result of this task order. However, the wiring of the electrical resistance heaters were changed on the horizontal unit which will be reflected in the Level 3 TDP at some later date.

A commercial compressor was substituted for the original military design compressor in the baseline units to determine suitability. The commercial compressor evaluation effort was abandoned following failure to meet cooling capacity requirement in accordance with the air conditioner specification.

2.2 Commercial Compressor (Copeland Corporation). The existing compressors used in the standard 18K BTUH air conditioners are source controlled items. The qualified sources of supply for the horizontal unit include Carrier Corporation, Welco Industries and Keco Industries, and for the vertical include Carrier Corporation and Welco Industries. These compressors are actually commercial units which are upgraded to withstand the military environment. The upgrades consist of cutting open the hermetically sealed compressors and upgrading the vibration mounts and/or rewinding or replacing the electric motor. This modification or militarization disrupts the mass production process and is therefore extremely costly to the Government. This

effort was intended to reevaluate current commercial compressors available, select the best candidate compressor, and to determine if it is suitable for use in the TECS air conditioners.

The Government tested the baseline air conditioners with the installed military compressors prior to the VSE TECS modification. Government testing included the following:

- o Performance
- o Cooling capacity and airflow
- o High temperature operation
- o Low temperature operation
- o Weight

The Government then replaced the military compressors with commercial compressors and started similar testing. The candidate commercial compressors were selected by VSE from GFD in the form of a market investigation. The VSE selection was based primarily on size and cooling capacity rating. VSE's calculations indicated that the cooling capacity of the commercial compressor selected (Copeland Corporation Model CRD1-0200-TF5, nominal rating - 24,000 BTUH) was marginal for the air conditioner. However, the size constraints of the air conditioner condenser compartment limited the size of the candidate compressor. The size of the next higher rated compressor was too large for the air conditioner. Government testing with the commercial compressors was to include the following:

- o Performance*
- o Cooling capacity and airflow*
- o Heating capacity
- o EMI emissions
- o Noise level
- o High temperature operation
- o Low temperature operation
- o Weight

*Only tests were actually performed.

The air conditioner cooling capacity with the commercial compressor was below the minimum required capacity specified in MIL-A-52767C. Therefore, the Government decided not to include the commercial compressors in the final TECS unit design. The Government then provided the baseline air conditioners to VSE as Government Furnished Equipment (GFE) for TECS modification. VSE replaced the commercial compressors with the original military compressors as a part of the modifications necessary to reconfigure these units to TECS units.

2.3 Controls/Run-in Testing. Following reconfiguration, a controls test was performed on three of the four baseline air conditioners. In addition to the controls test, an eight (8) hour run-in test was performed on three of the four air conditioners. During run-in, a portion of the condenser discharge air was ducted to the condenser intake such that 120°F inlet air temperature was maintained. The following data was measured and recorded each hour during the run-in test:

- o Condenser inlet air temperature

- o Evaporator inlet air temperature
- o Phase A current
- o Phase B current
- o Phase C current
- o Sight glass condition

Data sheets for the controls test/run-in test are provided in Appendix A. Formal testing was performed on TECS unit S/N's B009, 831747 and 831791. Testing was not performed on TECS unit S/N B007 since no motor controller was available. VSE was expecting delivery of a reworked motor controller from Southern Industrial Controls (Southcon) which would subsequently be installed in TECS unit S/N B007. However, due to the urgency of the TECS design verification testing program at Belvoir, the final baseline unit was delivered without a motor controller per Belvoir instructions. Prior to delivery of air conditioner S/N B007, VSE did determine TECS unit S/N B007 was functional using a motor controller from another TECS unit.

2.4 Engineering Evaluations and Design Modifications. No design modifications were made to the Level 1 TDP as a result of this task order. The location of the electrical resistance heater wiring was reconsidered under this task. Originally the heater banks were connected on the input of the motor controller. This configuration reduced the load on the motor controller during heating however, it necessitated an unbalanced load on the supply power source due to heater element design compromises required for the 208V, 3 phase and 230V, single phase input power conditions.

Connecting the heaters to the output of the motor controller adds a resistive load on the motor controller and provides for balanced loading on the supply power source. Keco Industries indicated that the increased resistive load on their motor controller would present no problems. Southcon on the other hand indicated concern about cooling of their power transistors under a 10 amp resistive load. Southcon's response was basically "try it and see" (See Appendix B for summaries of significant telephone conversations). Rewiring the heaters to the output of the motor controllers also enables the use of the original heater and heater bracket design for the 18K horizontal TECS unit. Belvoir decided to make this change to insure a balanced load condition on the supply power source. This change will be incorporated into the Level 3 TDP being developed for Belvoir by Radian, Inc. of Alexandria, VA.

3.0 CONCLUSION

Two (2) 18K horizontal TECS and two (2) 18K vertical TECS air conditioners were fabricated in accordance with GFD Level 1 drawings, subjected to controls and run-in testing (three units only), and delivered to Belvoir. VSE was not required to perform any design modifications to the TECS drawing packages as a result of Task 0136. Belvoir required modifications to the TECS heater configuration consisting of heater rewiring for the horizontal unit, and reversion to the previous heater element and heater bracket design used in the original 18K horizontal TECS TDP. This change will be incorporated into the TECS drawing package by another Government contractor responsible for Level 3 TDP development.

Commercial compressors were installed and tested by the Government in the 18K horizontal and vertical air conditioners prior to VSE conversion of the air conditioners into TECS units. Insufficient cooling capacity necessitated the Government to require VSE to replace the commercial compressor with the military design compressors during TECS prototype fabrication.

4.0 RECOMMENDATION

The military design compressors should be used in the 18K BTUH TECS air conditioners. The reduction in cooling capacity with the commercial compressor should not be acceptable. Though vibration testing was not performed with the commercial compressor, it is anticipated that failures would result due to the relatively light internal vibration mounts provided with a commercial unit.

The Belvoir test program should be completed to identify any undesirable operation of the 18K BTUH TECS air conditioners. Any modifications required should be performed on prototype TECS units and tested as quickly as possible to insure inclusion in the TDP for the upcoming TROSCOM, FY89 18K BTUH air conditioner procurement.

APPENDIX A

TEST DATA SHEETS - CONTROLS/RUN-IN TESTING

QC TESTING DATA SHEET FOR OPERATIONAL VERIFICATION OF TECS 18KBTU HORIZONTAL UNITS

S/N OF UNIT UNDER TEST 831791

DATE OF TEST 9-28-88

QC INSPECTOR R. Rouzee

A) FUNCTION TEST — QC INT.

1) WITH UNIT OFF AND POWER APPLIED TO J4 ROTATE MODE SWITCH TO THE VENT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN. — R

2) RETURN MODE SWITCH TO THE RESET POSITION AND WAIT APPROX. 6-7 SECONDS FOR THE UNIT TO RESET. — R

3) WITH THE TEMPERATURE SWITCH IN THE FULL CCW POSITION, ROTATE THE MODE SWITCH TO THE HEAT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 72 F — R

4) ROTATE THE TEMP SWITCH TO THE FULL CW POSITION. AN AUDIBLE CLICK SHOULD BE HEARD AND THE HEATERS SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 86 F IF THE TEMP IN STEP 4 IS HIGHER THAN IN STEP 3 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. — R

5) SAME AS STEP 2. — R

6) WITH THE TEMPERATURE SWITCH IN THE FULL CW POSITION , ROTATE THE MODE SWITCH TO THE COOL POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 79 F — R

7) ROTATE THE TEMP SWITCH TO THE FULL CCW POSITION. THE BLOWER SHALL SHUT OFF FOR APPROX. 6-7 SECONDS, AFTER WHICH THE COMPRESSOR SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 59 F IF THE TEMP IN STEP 7 IS LOWER THAN IN STEP 6 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. — R

B) ENDURANCE TEST

1) USING SOME TYPE OF DUCTING DEVICE DEFLECT THE HOT AIR OUTPUT INTO THE AIR INTAKE. USING A TEMP PROBE MONITOR THE TEMPERATURE OF THE INTAKE AIR SO THAT 120F IS MAINTAINED. RUN THE UNIT IN THE HIGH COOL MODE FOR A MINIMUM OF 8 HRS. UNIT SHALL NOT CUT OUT DURING THIS TIME. _____

TIME OF TEST START 9:00 AM

TIME OF TEST STOP 3:25 pm

DATE 9-28-88

COMMENTS/REMARKS: _____

TIME	T1	T2	SIGHT GLASS CONDITION	CURRENT RED	CURRENT WHITE	CURRENT BLACK
10:00	119	59	CLEAR/LIME	12.7	12.5	12.7
11:00	122	61	CLEAR/LIME	12.9	12.8	13.01
12:00	125	63	CLEAR/LIME	12.9	12.7	13.0
1:00	127	64	CLEAR/LIME	13.0	12.9	13.2
2:00	129	67	Clear/Lime	13.2	13.1	13.8
3:00		Shut down		14.7	14.6	15.1
START 1:30PM 9-29-88						
2:10	119	51	CLEAR/LIME	11.3	11.2	11.5
3:20	120	51	CLEAR/LIME	11.3	11.1	11.5
4:00	119	50	CLEAR/LIME	11.3	11.2	11.5
5:40	1189	51	CLEAR/LIME	11.2	11.1	11.5

5:45 SHUT DOWN

QC TESTING DATA SHEET FOR OPERATIONAL VERIFICATION OF TECS 18KBTU VERTICAL UNITS

S/N OF UNIT UNDER TEST B009

DATE OF TEST 9-1-88

QC INSPECTOR R. Rouzer

A) FUNCTION TEST — QC INT.

1) WITH UNIT OFF AND POWER APPLIED TO J4 ROTATE MODE SWITCH TO THE VENT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN. R

2) RETURN MODE SWITCH TO THE RESET POSITION AND WAIT APPROX. 6-7 SECONDS FOR THE UNIT TO RESET. R

3) WITH THE TEMPERATURE SWITCH IN THE FULL CCW POSITION, ROTATE THE MODE SWITCH TO THE HEAT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN.USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 76 F R

4) ROTATE THE TEMP SWITCH TO THE FULL CW POSITION. AN AUDIBLE CLICK SHOULD BE HEARD AND THE HEATERS SHALL COME ON.USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 81 F IF THE TEMP IN STEP 4 IS HIGHER THAN IN STEP 3 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. R

5) SAME AS STEP 2. ____

6) WITH THE TEMPERATURE SWITCH IN THE FULL CW POSITION , ROTATE THE MODE SWITCH TO THE COOL POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 82 F R

7) ROTATE THE TEMP SWITCH TO THE FULL CCW POSITION. THE BLOWER SHALL SHUT OFF FOR APPROX. 6-7 SECONDS, AFTER WHICH THE COMPRESSOR SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 74 F IF THE TEMP IN STEP 7 IS LOWER THAN IN STEP 6 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. R

B) ENDURANCE TEST

1) USING SOME TYPE OF DUCTING DEVICE DEFLECT THE HOT AIR OUTPUT INTO THE AIR INTAKE. USING A TEMP PROBE MONITOR THE TEMPERATURE OF THE INTAKE AIR SO THAT 120F IS MAINTAINED. RUN THE UNIT IN THE HIGH COOL MODE FOR A MINIMUM OF 8 HRS. UNIT SHALL NOT CUT OUT DURING THIS TIME.

TIME OF TEST START 9:45 AM retest 1:30 PM

TIME OF TEST STOP 5:45 4:30 PM

DATE 9-1-88 9-2-88

COMMENTS/REMARKS: T2 Temp. increased steadily throughout test. Upon investigation by PE valve ___ was found to be "sticky". Valve was cleaned and unit was run for approx. 3 HRS. CONDENSOR INPUT Temp 121°F, output air 52°. Upon removal of ducting by QC output air temp rose to 61°F, held for 30 sec and dropped to 56°F where it stabilized. Unit was shut off. After reset unit output air temp decreased to mid 40's. Valve still appears to be "sticky" 9-2-88

TIME	T1	T2	SIGHT GLASS CONDITION	CURRENT A RED	CURRENT WHITE	CURRENT C BLACK
			SOLDER CHIP @ START			
9:45	122	67	LIME/CLEAR	8.4	9.2	8.7
10:45	123	68	LIME/CLEAR	8.6	9.2	8.8
11:45	120	71	LIME/CLEAR	7.9	8.7	8.2
12:45	121	72	LIME/CLEAR	8.0	8.8	8.3
1:45	122	73	LIME/CLEAR	7.9	8.8	8.4
2:45	121	73	LIME/CLEAR	7.9	8.5	8.2
3:45	122	74	LIME/CLEAR	7.8	8.5	8.1
4:45	120	74	LIME/CLEAR	7.5	8.4	8.0
5:45	119	75	LIME/CLEAR	7.4	8.4	7.8

QC TESTING DATA SHEET FOR OPERATIONAL VERIFICATION OF TECS 18KBTU HORIZONTAL UNITS

S/N OF UNIT UNDER TEST 831747

DATE OF TEST 8-30-88

QC INSPECTOR R. ROUZER

A) FUNCTION TEST — QC INT.

1) WITH UNIT OFF AND POWER APPLIED TO J4 ROTATE MODE SWITCH TO THE VENT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN. R

2) RETURN MODE SWITCH TO THE RESET POSITION AND WAIT APPROX. 6-7 SECONDS FOR THE UNIT TO RESET. R

3) WITH THE TEMPERATURE SWITCH IN THE FULL CCW POSITION, ROTATE THE MODE SWITCH TO THE HEAT POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL START TO RUN.USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 70 F R

4) ROTATE THE TEMP SWITCH TO THE FULL CW POSITION. AN AUDIBLE CLICK SHOULD BE HEARD AND THE HEATERS SHALL COME ON.USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 75 F . IF THE TEMP IN STEP 4 IS HIGHER THAN IN STEP 3 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. R

5) SAME AS STEP 2. R

6) WITH THE TEMPERATURE SWITCH IN THE FULL CW POSITION , ROTATE THE MODE SWITCH TO THE COOL POSITION. AFTER APPROX. 6-7 SECONDS THE BLOWER SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 75 F R

7) ROTATE THE TEMP SWITCH TO THE FULL CCW POSITION. THE BLOWER SHALL SHUT OFF FOR APPROX. 6-7 SECONDS, AFTER WHICH THE COMPRESSOR SHALL COME ON. USING A TEMPERATURE PROBE VERIFY THE TEMPERATURE OUTPUT. TEMP 56 F . IF THE TEMP IN STEP 7 IS LOWER THAN IN STEP 6 THEN THE THERMOSTAT IS FUNCTIONING PROPERLY. _____

WASHINGTON REGION QUALITY CONTROL

SHOP REQUEST FOR INSPECTION

FORM

DATE: Aug 29, 1988 TIME: 12:45 JOB No.: 0500-0136

DWG No.: 10451 HORIZONTAL 831747

ITEM DESCRIPTION: Elec check out Ser. No. 747

TYPE OF INSPECTION REQUIRED:

IN-PROCESS ✓

WELDING ___

FINAL ___

OTHER _____

INSPECTION REQUESTED BY: Ralph M Hyde

SPECIAL INSTRUCTIONS: _____

_____

_____

_____

QC FORM XXXX

APPENDIX B

SIGNIFICANT TELEPHONE CONVERSATIONS

TELECON

JOB NO.: 0500.0136 TITLE: TECS - 1st Article

DATE: 10/18/88 TIME: 10:30 AM

~~CALLED~~ CALLER: Bob Sherfy

~~CALLER~~ CALLED: PERSON: John Dupps

COMPANY: Kreo Industries, Inc

ADDRESS: Florence, KY

PHONE: (606) 525-2102

SUBJECT: Motor Controller Output (John Dupps returned my call to him yesterday)

SUMMARY OF CALL: When I asked if the Kreo MC controls output voltage when input voltage is varied, his answer was yes, probably within 5%. This is done by sensing the DC bus voltage and varying the pulse width. Pulse width decreases at higher input voltages and increases at lower input voltages to yield a relatively constant RMS equivalent output voltage. Where Southern recently expressed some concern over running a resistive load on the MC output, Kreo sees no problem. John is working on increasing output current to operate units at 120°F/120°F conditions. I reminded him of the simultaneous low voltage requirement.

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Tom Sgro/Chris Bolton

Lincoln Hwy

0136 and 0074 files

TELECON

JOB NO.: 0500.0136 TITLE: TECS-18 BASELINE

DATE: 10/17/88 TIME: 2:30 PM

CALLER: BOB SHERFY

CALLED: PERSON: JIM BRADLEY

COMPANY: SOUTHCON.

ADDRESS: CHARLOTTE, NC

PHONE: (704) 588-8000

SUBJECT: Motor Controller Output

SUMMARY OF CALL: I asked Jim if the Southcon MC's output voltage is controlled so that it will not vary as the input voltage changes from 187 VAC to 253 VAC. He replied yes, it probably does not get higher than about 215 VAC. He was more vague about low voltage, however, implying that there is also control under low voltage conditions but not using exact numbers. Jim was somewhat concerned about using more than about 10 amps into a resistive load. He said give it a try and see what happens. His concern is for cooling of the power transistors which must operate continuously with a resistive load. (Output RMS voltage is controlled by varying pulse width.

DISTRIBUTION:

Tom Sgro / Charles Burton

Lincoln Nax.

File's 0074 and 0136.